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MANAGEMENT AND CONTROL OF COMBINED SEWER OVERFLOWS--PROGRAM OVERVIEW

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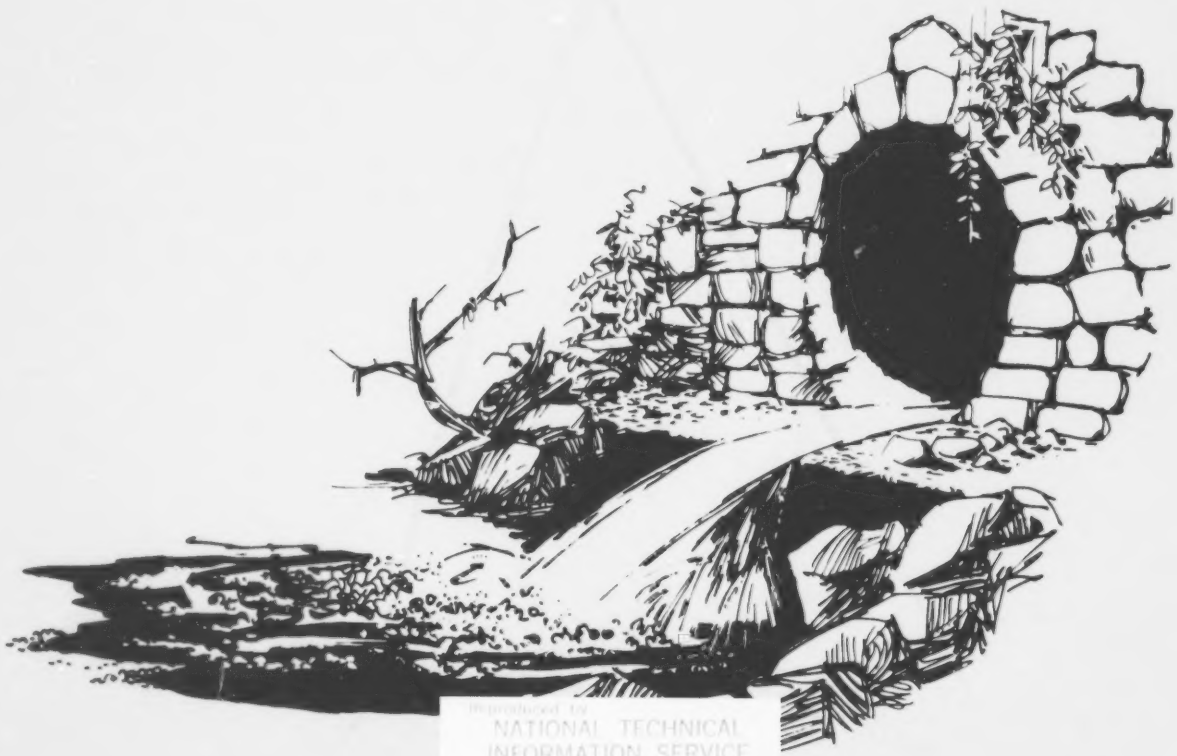
Management and Control of Combined Sewer Overflows

PROGRAM OVERVIEW



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PB 229 575

MANAGEMENT AND CONTROL OF COMBINED SEWER OVERFLOWS

Program Overview

by

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Edison, New Jersey 08817

E R R A T A S H E E T

TO: Recipients of Report, "Management and Control of Combined Sewer Overflows - Program Overview"

It has been found necessary to make the following changes to the report:

1. Page 3, third paragraph: After the last sentence, add the following new sentence, This can produce "shock loadings" detrimental to receiving water life.

2. Page 4, second sentence: Add number 41 to references.

3. Page 7, first sentence under V. Corrective Methods: Change sentence to read as follows, Program (16, 40) research, development and demonstration projects have provided significant results, and have illustrated that alternatives to sewer separation in most cases are the logical course of action.

4. Page 14, first sentence: Replace the word system with pipelines.

5. Page 19, first paragraph: After the fifth sentence (line 10) add, Additional benefits of tunnel or in sewer storage are attributed to the installations coverage of an expanded area or length. Because of this, storage is more readily available to remote areas; hydrographs can possibly be smoothed or volumetrically reduced for facility design since many intense storms are over small areas; and, excessive overflows, greater than storage capacity, could be selectively and automatically discharged to stream locations based on water usage and assimilation capacity.

6. Page 25, third line: Change the word concnetration to concentration.

7. Page 30, first paragraph: After the last sentence add, The designer, in his evaluation of the optimum surge-treatment system, should recognize the wet-weather treatment plant's capability to continuously draft stored flow while it is raining.

8. Page 32, first paragraph: In the third complete sentence (line 11) eliminate, during the year.

9. Page 32, first paragraph: Change the last sentence to read, It may very well be, that the temperature fluctuation during the year in combined sewage in many urban areas would be similar to the range ($40^{o}F$ to $80^{o}F$) tested for by Benarde, et al., and as a result, require disinfectant dosage to vary seasonally or as affected by ambient temperature.

10. Page 32, second paragraph: In the second sentence add a comma after Philadelphia.

11. Figure 12: Change the word solid in the caption to solids.

12. Page 38, second paragraph: In the first sentence eliminate the word rapid and change references (106, 107) to (109, 110).

13. Page 38, second paragraph: Add at the end of the second sentence, (111).

14. Page 41, second paragraph: In lines 6 and 7 add commas after references 127 and 128.

15. Page 42, second paragraph under VII. CONCLUSION: Add after the last sentence, Many concepts are also adaptable for sanitary sewage.

16. Page 43, first paragraph under VIII. ACKNOWLEDGEMENTS: In the first sentence (line 2) add a semicolon after Division.

17. Page 53, Reference Number 117: Change 1971 to 1972.

MANAGEMENT AND CONTROL OF COMBINED SEWER OVERFLOWS

I. PREFACE

This paper will serve as a basic overview of the U.S. Government's involvements toward developing countermeasures for combined sewer overflow pollution.

The "Storm and Combined Sewer Pollution Control Research, Development and Demonstration Program" was initiated not too long ago, under the auspices of the U.S. Public Health Service, Department of Health, Education and Welfare (PHS). In their (PHS) report (1) published in 1964, the nationwide significance of pollution caused by storm generated discharges was first identified. After going through several Federal Agency and name changes, the Program is now part of the Office of Research and Monitoring, U.S. Environmental Protection Agency (USEPA). Up to the present time over 100 grants and contracts totalling approximately $80,000,000, have been awarded. USEPA's share being in the neighborhood of $40,000,000.

II. INTRODUCTION

The earliest sewers were built for the collection and disposal of storm waters, and for convenience emptied into the nearest watercourse. In later years, house sewage was discharged into these large storm drains, automatically coverting them into "combined" sewers. Subsequently, combined sewers came into widespread use in communities because they represented a lower investment than the construction of separate storm and sanitary sewers.

When the problems of sanitary sewage became recognized, the engineer was confronted with how best to separate wet from the dry-weather flows to enable proper treatment of the sanitary sewage portion. This was overcome by designing overflow structures at selected points in the sewerage system. New sewers were installed for intercepting and conveying the dry-weather flows to the local sewage treatment works, whereas, combined sewage flows greater than a predetermined multiple of mean dry-weather flow were discharged directly into the receiving stream.

Overflow or relief points are also integral to separate sanitary systems. Nominal allowances are made for infiltration which increases with pipe age. This problem is compounded by unauthorized connections, and reliefs in the "so-called" separate sanitary system are used as an immediate and low cost solution. Studies conducted for the USEPA in Roanoke, Virginia(2); Oakland and Berkely, California(3); and by others(4) found that separate systems, with excessive infiltration and other inflows, act essentially as combined sewer systems.

The basic difficulty with combined and "nominal" sanitary sewers involves their "built-in" inefficiencies, which are their overflow points. This will be further explained in the following section.

III. COMBINED SEWER OVERFLOW PROBLEMS

Untreated overflows from combined sewers, particularly during wet-weather, has proved to be a substantial pollution source(5,6,7,8,9,10,11,12) in terms of impact upon receiving stream water quality (9,10,13,14)--even though the percentage of sanitary sewage lost from the system by overflow is small, that is, in the order of 3 to 5 percent(15,16,17,18,19).

Pollution problems stemming from combined sewer overflows are widely distributed throughout the United States; the Northeast, Midwest, and Far-West being the principal areas of concentration. All told nationwide, there are estimated(20) to be over 3,000,000 acres of combined sewer drainage area contained in more than 1,300 municipalities with a population of 54 million served by some 55,000 miles of combined sewers.

The magnitude of the overflow problem was exemplified by a 2-year study(21) conducted on a 229 acre combined sewer watershed in Northampton, England. This study showed that the cumulative yearly biochemical oxygen demand (BOD) load in the combined sewer overflows nearly equaled the BOD load contained in the effluent of the local secondary treatment plant. Suspended solids within the overflows were three times the load contributed by the treatment works effluent.

The relatively poor flow characteristics of combined sewers during dry-weather when sanitary wastes alone are carried, encourages settling and build-up of solids in the lines until a surge of flow caused by a rainstorm purges the system. Studies(18,22,23) in Buffalo, New York have shown that 20 to 30 percent of the annual collection of domestic sewage solids are settled and evenutally discharged during storms. As a result, a large residual sanitary pollution load, over and above that normally carried is discharged over a relatively short interval of time, oftentimes resulting in what is known as a "first flush" phenomenon.

Aside from the raw domestic (and industrial) sewage carried in the overflow, non-sanitary urban runoff in itself is a significant contributor to the overflow pollution load(7,10,12,24,25,26,27). As the storm runoff drains

from urban land areas, it picks up accumulated debris; animal droppings; eroded soil(28,29,30); tire and vehicular exhaust residue; air pollution fallout; deicing compounds(31,32), pesticides(33,34,35), fertilizers and other chemical additives; decayed vegetation; together with many other known and unknown pollutants(34,35,36,37). A study(34,35) on a 1,067 acre drainage basin in Durham, North Carolina has shown that the annual BOD contribution attributable to surface wash from storms is approximately equal to that contribution of the secondary treated sanitary effluent, and the total organic matter (chemical oxygen demand[COD]) was estimated to exceed the amount in the raw sanitary sewage from a residential area of the same size.

It is important to note that there is no apt description of "typical" combined sewage or stormwater runoff characteristics due to the variable nature of the rainfall-runoff patterns. Tables I and II serve to illustrate the general concentration ranges of the wastewater constituents listed for combined sewer overflow and urban stormwater runoff, respectively.

III. SEWER SEPARATION

When considering combined sewer overflow problems, first attention is generally given to the construction of separate sanitary and storm sewer systems. In constrast, the 1964 PHS study(1) stipulated that alternative solutions be investigated to determine if means other than sewer separation could be found at lower cost.

An American Public Works Association (APWA) study of combined sewer problems indicated that if all communities with combined sewers in this country were to effect sewer separation, they would face an expenditure of approximately 70 billion dollars at today's cost(38). It was further estimated

TABLE I

CHARACTERISTICS OF COMBINED SEWER OVERFLOWS
(SELECTED DATA)

BOD_5	-	30	TO	600	MG/L
TSS	-	20	TO	1,700	MG/L
TOT. SOL.	-	150	TO	2,300	MG/L
VOL. TOT. SOL.	-	15	TO	820	MG/L
PH	-	4.9	TO	8.7	
SETTL. SOL.	-	2	TO	1,550	ML/L
ORG. N	-	1.5	TO	33.1	MG/L
NH_3N	-	0.1	TO	12.5	MG/L
SOL. PO_4	-	0.1	TO	6.2	MG/L
TOT. COLI.	-	20,000	TO	$90x10^6$/100	ML
FEC. COLI.	-	20,000	TO	$17x10^6$/100	ML
FEC. STREP.	-	20,000	TO	$2x10^6$/100	ML

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FEC. COLI.	-	20,000	TO	$17x10^6$/100	ML
FEC. STREP.	-	20,000	TO	$2x10^6$/100	ML

TABLE II

CHARACTERISTICS OF URBAN STORMWATER
(SELECTED DATA)

BOD_5	-	1	TO	>700	MG/L
COD	-	5	TO	3,100	MG/L
TSS	-	2	TO	11,300	MG/L
TOT. SOL.	-	450	TO	14,600	MG/L
VOL. TOT. SOL.	-	12	TO	1,600	MG/L
SETTL. SOL.	-	0.5	TO	5,400	ML/L
ORG. N	-	0.1	TO	16	MG/L
NH_3N	-	0.1	TO	2.5	MG/L
SOL. PO_4	-	0.1	TO	10	MG/L
TOT. PO_4	-	0.1	TO	125	MG/L
CHLORIDES	-	2	TO	25,000	MG/L*
OILS	-	0	TO	110	MG/L
PHENOLS	-	0	TO	0.2	MG/L
LEAD	-	0	TO	1.9	MG/L
TOT. COLI.	-	200	TO	146×10^6/100	ML
FEC. COLI.	-	55	TO	112×10^6/100	ML
FEC. STREP.	-	200	TO	1.2×10^6/100	ML

*WITH HIGHWAY DEICING

that the use of alternate measures could reduce this cost to about 25 billion dollars.

It is again emphasized that urban stormwater runoff itself can be a significant source of stream pollution. Sewer separation would not cope with this pollutional load. An EPA study(27) conducted in Bucyrus, Ohio, revealed that if separation were used, the reduction in wet-weather pollution would be only 50 percent. The other 50 percent would remain in the untreated urban storm runoff.

IV. LEGISLATION

The Federal Water Pollution Control Act(39) recognizes the problem of combined sewer overflows and accordingly authorizes funds for the development of new and improved methods for controlling this source of pollution. Demonstration grants can be made to any State, municipal, intermunicipal, or interstate agency in amounts of up to 75 percent of the estimated project cost. Contracts are also available to research and development oriented firms for the implementation of worth-while projects.

V. CORRECTIVE METHODS

Our Program (16,40) has now funded over 100 research, development and demonstration projects which have provided significant results, and have illustrated that alternatives to sewer separation in most cases are the logical course of action. The Storm and Combined Sewer Pollution Control R&D Program has categorized three basic approaches other than sewer separation. These are: control, treatment, and combinations of the two, which are discussed in this section as follows:

A. Control

Control of combined sewer overflows can be obtained by reduction or equalization of peak stormwater flows, improved sewerage system usage, and minimizing infiltration.

1. Existing System Control

Let us start by indicating what the "operator" can do to get the most out of what he has to work with.

a. Maximize Sewage Treatment at Sanitary Plant During Wet-Weather

First of all, he should try to contain as much flow or treat as much sewage as possible during a storm flow occurrence. This would serve to reduce wet-weather bypassing which at the beginning of storm flow can have a high pollutant concentration, as previously described. It is recognized this extra plant burden may decrease treatment efficiencies somewhat, and create added sludge or solids handling problems. However, these practices for only short periods during storm flows, are well worth the effort. If the operator determines the hydraulic loading will cause a serious upset of a unit process(es), then primary treatment plus disinfection, should be considered as a minimum measure.

In Detroit(41), where the prevailing direction of storms is known, the operator receives advanced information on storms from a remotely stationed rain gage. The treatment plant pumping is increased, thus lowering the interceptor gradient and

allowing for greater interceptor storage capacity and conveyance. This practice has enabled the city to entirely contain and treat many intense spot storms, plus many scattered city-wide rains.

b. Improve Regulator Maintenance

The operator should concern himself with improved regulator inspection and maintenance and preventive schedule so as to minimize the occurrence of overflows(38,41,42,43). Overflows during dry as well as wet-weather due to malfunctioning devices, can thus be alleviated. Tide gate conditions allowing backwater intrusion can be corrected, and diversion structure settings can be raised to obtain more interceptor carrying capacity. The USEPA has long realized the need for better operation of overflow regulators and accordingly, the APWA has recently completed a study resulting in two publications(42,43); 1) a state-of-the-art assessment on, "Combined Sewer Regulator Overflow Facilities", and 2) "Combined Sewer Regulation and Management, A Manual of Practice".

Next, how may municipalities control combined sewer overflows without large and costly modifications? Here we are concerned with: 1) infiltration and extraneous inflow control; 2) "housekeeping", such as cleaning of street surfaces, catch basins, and sewer lines to reduce solids, etc.; 3) the possible use of friction reducing polymers to increase flow carrying capacity; and 4) the implementation of certain land use regulations, zoning requirements and construction site (and

other) erosion control practices, all of which would be helpful in reducing runoff contamination by solids and other substances.

c. Infiltration and Extraneous Inflow Control

Most consulting engineers and municipal people will agree that excess flow due to infiltration is a major thief of capacity which should otherwise be available to transport sewage, and can thereby affect proper operation of sewerage systems, and consequently, the quality of our streams. Other adverse impacts due to infiltration include(38,44,45,46): 1) surcharging and backflooding into streets and private areas, and need for relief sewers ahead of schedule; 2) surcharging of treatment plants and pumping stations, causing flow bypassing, decrease in treatment efficiency, and higher treatment costs; and 3) greater incidence and duration of overflows, and diversion of raw sewage. The APWA has reported that infiltration was a pronounced problem during dry-weather in 14 percent of communities surveyed(38), and 53 percent of the communities during wet-weather. The APWA also indicates(44,45) that other sources of extraneous inflow compounding the problem include: roof leaders; depressed manhole covers; cellar, foundation and yard drains; air conditioning and industrial cooling waters; and other connections(46).

Control of infiltration should first take place during sewer pipe installation. Better construction materials are necessary together with proper installation techniques(44,45,46).

Preliminary laboratory testing(47) has indicated that conventional sewer pipe can be coupled with durable, watertight joints using heat shrinkable plastic tubing made of polyolefin-polymeric base hot melt adhesive, a material shown to be superior and economically comparable to existing jointing mechanisms. The new methods of sewer sealing should be fully evaluated before major rehabilitation or replacement is undertaken. Shrinkage upon drying, and structural weakness previously associated with the conventional sealants, may possibly be minimized using modified polymeric and other new materials(48). Limited tests(49) have shown that significant corrosion resistance may possibly be achieved through the employment of such surface coatings as: vinyl-vinylidene chloride, vinyl acetate-acrylic, nitrile rubber latex, nitrile-phenolic rubber, an emulsified reclaimed rubber, and a rubber base adhesive,at one-tenth the cost of epoxy and plastic liners. Improvements in corrosion resistance, impermeability, and strength of concrete pipe can also be achieved by impregnation with such materials as hydrofluoric acid and sulfur(49).

Infiltration surveys should be undertaken when extraneous inflows are suspected. Such surveys may use T.V. and other visual pipeline inspection, smoke tests, air and water pressure tests, and various flow techniques. Figure 1 illustrates the result of an infiltration smoke test. The APWA under USEPA sponsorship has developed a manual of practice(45) on infiltration control containing guidelines on allowable inflow, con-

struction methods and materials, and types and application of sewer sealants for reducing infiltration.

Building connections to street sewers are a major source of infiltration(44,50). As much as 70 to 80 percent of the infiltration load can occur in these lines. Accordingly, the aforementioned infiltration control practices should be strictly followed here.

The City of Springfield, Illinois Sanitary District has recently engaged in a concerted program to remove improper connections and extraneous inflows to their sewerage system(50). Over a two-year period utilizing a public relations campaign, various questionnaires, building inspections, and good follow-up effort, the District was able to substantially reduce downspout connections to its sewers. Besides improving the use of the sewerage system, the profound significance was in the elimination of numerous public complaints regarding basement flooding. From a cost standpoint, the District has estimated that the cost of removing the roof leaders will be fully returned within 16 months by virtue of reduced operation and maintenance costs for the sewerage system.

However, before a municipality considers removing extraneous inflows, the following basic factors should be considered:

1) Determination of what a "clean" or unpolluted inflow really is. For instance, subsurface drainage may be

contaminated leachate or contain toxic material washed from basement floors.

2) Sewer septicity and odor conditions which may arise because of lowered flow from the elimination of long-standing inflow sources.

3) Effect on the public of any sudden decision to eliminate inflow sources and the associated problems of enforcement.

4) The strong possibility that communities will be forced to treat separate urban runoff sometime in the future, indicates that the re-connection of certain so called "clean" waters from sanitary to storm drains may be a practice done in vain.

d. Surface "Housekeeping"

Studies(37,51) have indicated that it may be cheaper to remove solids from the street surfaces by sweeping, etc. than by eliminating them via the sewerage system. One set of figures received(51) showed street sweeping to cost 25 to 30 dollars per ton of solids removed as compared to 60 to 70 dollars per ton of solids removed by way of the sewerage system. What may even be more important is that the wet-weather overflow polluting potential of these solids are eliminated by the urban surface removal practice. Certain land use, zoning(25,41), and construction site erosion control practices(25,28,29,30) are other ways of alleviating the solids burden to the receiving streams or treatment plants by surface source prevention.

e. Polymers to Increase Flow Capacity

If there is insufficient carrying capacity in the system, polymer addition may serve to measurably reduce fluid friction. Recent research(52,53,54) for the USEPA has shown that polymeric injection can increase flow capacity as much as 2.4 times at a constant head. This method can be used as a short or long-term measure to correct troublesome pollution-causing conditions such as localized flooding and excessive overflows. A preliminary cost comparison(53) for a 15-inch sewer in Garland, Texas, indicated that polymer use for overflow control would cost one-fourth as much as relief sewer construction. However, additional cost verification is necessary for other locations.

2. Advanced Control Systems

In this segment of the paper, some of the newer and more advanced technology being developed by our Program will be described.

a. Flow Regulation

Several methods have been used to reduce operation problems associated with the conventional regulator devices. Cincinnati, Ohio(55) utilizes telemetered monitoring to detect unusual or improper dry-weather overflows. More sophisticated approaches are being applied by the Minneapolis-St. Paul Sanitary District and the Cities of Detroit, and Seattle. Funded by Federal grants, all three jurisdictions are making use of unused storage capacity within the existing sewerage system for the purpose of reducing the frequency and volumes of overflows(41,42,43,56,57). The general approach comprises remote monitoring of rainfall, flow levels,

and sometimes quality, at selected locations in the network, together with a centrally computerized control console for positive regulation of the overflow structures. In developing abatement programs for the combined sewer communities, this type of system should be considered as a major first step to minimize overflow occurrences. Figure 2 depicts the computer console and strategy room in Seattle, Washington and is a preview of what the operator in 1980 may be contending with.

New types of regulators are showing considerable promise(41,42,43). Positive control gates and inflated rubberized-fabric dams have been used by Minneapolis to regulate flows as part of their demonstration(42,43,56) project. A USEPA project in Philadelphia, Pennsylvania(42,43,58,59) has resulted in the development of a unique overflow device now being designed for full-scale demonstration, utilizing fluidic technology. This device requires no moving parts or external power since operation is entirely dependent upon motion of the wastewater. Improved regulator capability, as well as reduced operation and maintenance costs, are anticipated. Additional improvement in regulators is now in progress.

b. Storage

Storage offers direct control by containing the wastewaters produced during wet-weather periods. In-system storage by taking advantage of excess capacity in the trunk or interceptor sewer has been previously cited. The use of storage facilities

Figure 1. Using the smoke test to detect an infiltration problem, Montgomery Co., Ohio.

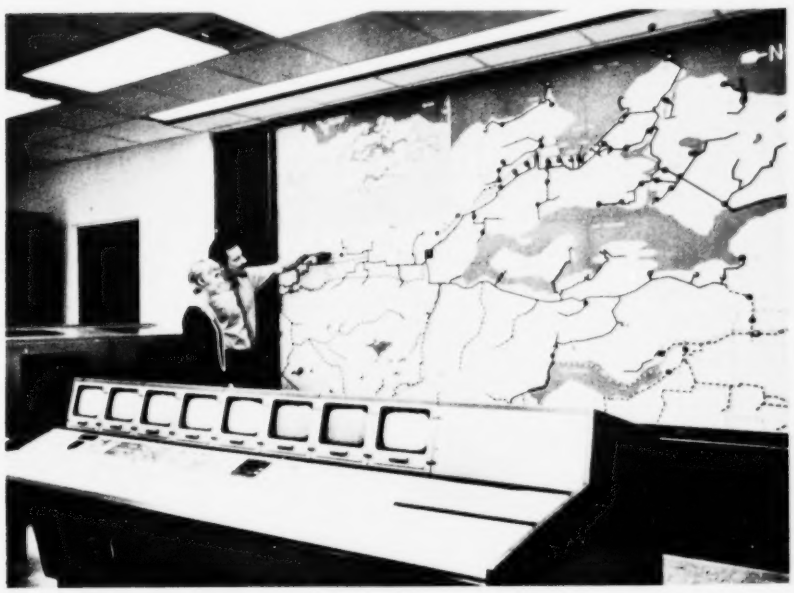

Figure 2. Computer console for augmented flow control system, Seattle, Washington.

for controlling combined sewer overflows has been convincingly demonstrated. The general procedure involves the return of retained overflows to the conventional treatment works for subsequent treatment during low flow, dry-weather periods.

Concrete (and steel) holding tanks are the most commonly used type of storage facility(15,16,60,61,62,63,64,65,66,67,68). The storm stand-by tanks at Columbus, Ohio constructed as early as 1932, were recently modernized(62,65) through USEPA grant assistance, by installation of sludge collection and automatic flow control equipment. Figure 3 shows the Columbus tanks. The City of Boston has commenced operation of an overflow holding tank(61,67) designed to provide 10-minute settling plus chlorination for treating excess overflows of 233 million gallons per day (MGD). New York City(68) and Milwaukee have similar facilities under construction. Chippewa Falls, Wisconsin has constructed an asphalt-lined basin providing storage for up to 3.5 million gallons of overflow(53). These last four projects have also been supported by the USEPA R&D Program. Figure 4 shows the Chippewa Falls installation. A concept worthy of notation here, which was successfully demonstrated in London, England, is the conversion of existing or abandoned sanitary treatment units, in this case sedimentation tanks, to storm holding facilities as part of a plant expansion(69). Also, Orchard Park, Erie County, New York has proposed plans to utilize an abandoned trickling filter as a storage tank for stormwater infiltration(70).

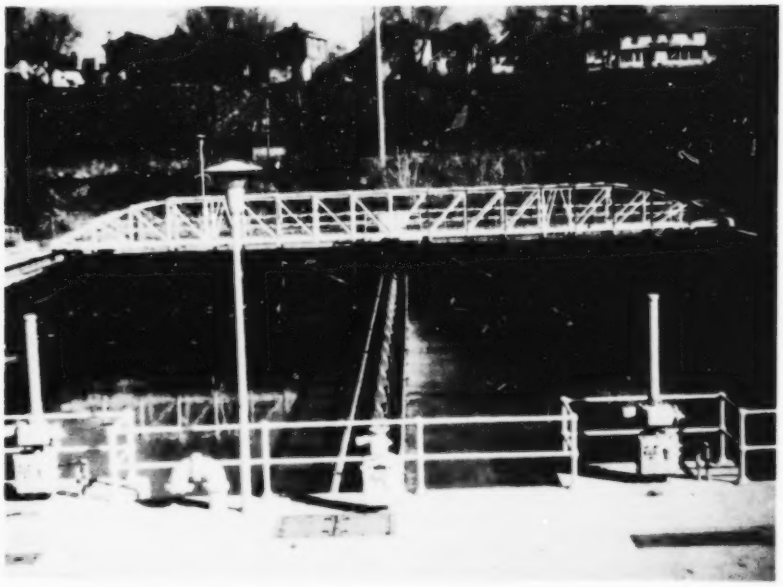

Figure 3. Storm Stand-by tank with upper portion of sludge collection mechanism visible, Columbus, Ohio.

Figure 4. Asphalt-lined basin providing storage for up to 3.5 MG, Chippewa Falls, Wisconsin.

Two basic problems encountered by conventionally-designed storage facilities in urban areas are land cost and availability, and adverse aesthetic impacts. In this regard, the USEPA is seeking new concepts. A major demonstration in Chicago(41,71,72,73) involves the new concept of "deep tunnels"(22,53). Chicago is constructing a 12-foot and 17-foot diameter deep tunnel, which is over 4 miles in length. The cost of a Metropolitan Chicago tunnel storage system is estimated at one billion dollars as contrasted to four billion for sewer separation. Another subsurface storage idea that is to be demonstrated by our Program is the underground "silo". The use of a 50-foot diameter, 100-foot deep silo could afford over 1 million gallons of storage.

Other designs with little or no urban land requirements include off-shore storage and the use of natural underground formations. Two USEPA demonstration projects(74,75) have evaluated the use of flexible neoprene-coated nylon fabric material as underwater containers, for the temporary storage of combined sewer overflows in the Washington, D.C. area. Figure 5 illustrates a conceptual drawing for off-shore storage in Cleveland, Ohio(76,77).

Design criteria should be based upon the pollution abatement results expected. For example, Milwaukee utilizes a mathematical model to determine size and projected efficiency of their holding tanks(78). The engineer and operator will be inter-

ested in the sludge-handling aspects of temporary storage. Two possibilities are: The re-suspension of solids by agitators or other means; and settling prior to pump-back (or bleed-off). Re-suspension can provide easier draw-off and is being evaluated by the Program. However, if sludge is settled, on-site sludge disposal in lieu of solids pumped back in stored flow, should be considered.

c. Porous Pavement

Another method to attenuate flows, having exhibited laboratory and pilot-scale feasibility(79), is by the installation of porous pavement. This pavement is made of asphalt-cement, and has been developed for structural soundness and an ability to allow 60 inches per hour of rainfall to permeate through its depth while retaining water at 15 percent of its bulk volume. If this material were to be used for major highway, street, parking lot, etc. paving projects, it would have the potential for reducing capacity and associated costs for both sewer and wet-weather flow treatment systems, a feature attributable to the porous pavement's ability to equalize flows entering or divert flows away from the sewerage system. This type of pavement installation can also offer a substantial benefit by recharging water supplies. However, when porous pavement is considered, we must realize that such features as geographical area temperature, sub-surface soil condition, and the possibility of groundwater contamination may play an important part in design and site selection.

d. New Sewer Systems

New types of sewer systems based on vacuum and pressure operation are being demonstrated. By using a pressure or

vacuum system for the collection and conveyance of sanitary sewage, we can reduce the waste volume generated, reduce conduit sizes, eliminate infiltration, minimize associated installation and treatment costs, and also alleviate overflows. The American Society of Civil Engineers(80) has completed a feasibility study on installation of pressure sewers within existing combined sewers as an alternate means of sewer separation. It was found that the vast majority of lines in urban systems are too small in diameter for this type of installation.

A pressure system in the Albany, New York area(81), being demonstrated successfully, employs previously developed(80) grinder-pump units placed in twelve homes for macerating and transferring sewage through 1-1/4" diameter plastic (polyethylene) pipe into a 3" plastic pressure header pipe in the street. It is hoped the pressure sewer system will serve as an adjunct to conventional gravity sewers and offer the designer a new degree of freedom in providing sewer service. In the meantime, this approach is available to solve current, non-system oriented problems as connecting low-lying units such as lake-front cottages and low-lying basements to the existing sewerage system.

B. Treatment

Other than waste storage, it may be considered necessary that combined sewer overflows be treated, either at the individual outfall locations, or at a centralized facility. It is noted that centralization, although offering benefits in reduced plant costs, invariably

requires high expenditures for the installation of large, combined sewer transport conduits or interceptors.

Conventional treatment processes apply basically to the nearly steady-state conditions of sanitary sewage, whereas, combined sewer overflows occur on an intermittent and random basis. Following rainfall, these flows exhibit highly-varying patterns in both quality and quantity over short periods of time(10,15,16,20,56,82). No data on quality of either combined sewage or urban stormwater can be considered "typical". Unlike municipal sewage, we cannot typify BOD and suspended solids concentration for design or operation of abatement facilities. Consequently, it has been diffiuclt to directly adapt existing treatment methods to storm generated overflows, especially the microorganism dependent biological processes. Adverse flow conditions and unpredicable shock loadings make it advisable to consider the newer chemical and/or physical treatment techniques, and the incorporation of automated control into the intended storm treatment facility to achieve optimum efficiency.

Rather than independent units, biological treatment systems are applied by our Program as auxiliary facilities at the conventional sewage plant for treating excess flows. Two such biological treatment processes are on-going USEPA projects. One uses activated sludge to treat overflows at Kenosha, Wisconsin. The other at New Providence, New Jersey utilizes plastic media, and compares this with standard rock media, in high-rate trickling filters for treating sanitary sewage with a high degree of infiltration.

Treatment methods currently under investigation by the Storm and Combined Sewer Pollution Control Program include the following(16,40, 41,53):

1. Fine-mesh screening and microscreening
2. Dissolved-air flotation
3. Rotating biological contactors
4. High-rate plastic media trickling filters
5. High-rate, single and multi-media filtration
6. Vortex and helical separators
7. Advanced disinfection methods, e.g., high-rate application, on-site generation, automated operation, ozonation, and use of combined halogens (chlorine and iodine) and chlorine dioxide
8. Tube settlers
9. Powdered and granular activated carbon adsorption
10. Polymer and other chemical additives for improved settling(83), microscreening, filtration, and flotation
11. Chemical oxidation
12. In-line or in-sewer treatment
13. Sludge handling and treatment
14. Regeneration of carbon and coagulants, and
15. Reclamation and reuse

Time does not allow a detailed discussion of each of these methods. However, mention of some of our more promising combined sewer overflow treatment projects is worth-while.

Since high throughput rates are necessary for combined sewer overflows, the conventional treatment processes are being studied for possible modifications. For example, the microstrainer is conventionally designed for polishing secondary sewage plant effluent at an optimum rate of around 10 gallons per minute per square foot (gpm/ft^2)(84). Tests on a pilot microscreening unit in Philadelphia(85,86) supported by USEPA funds, are showing that(87) at high flux rates of 35 to 45 gpm/ft^2, suspended solids removals in combined overflows exceeding 99 percent can be achieved. Since overflows are not continuous as sanitary flows are, occurring about three percent of the total time, a sacrifice of screen life for increased hydraulic treatment rate is worthwhile. (A similar philosophy applied to grit removal for the purpose of extending the useful life of piping, pumps and appurtenance, indicates the requirement for degritting needs re-evaluation for combined sewer overflow treatment, and possibly elimination in many design considerations.)

At this point it is appropriate to bring out an important fact of which future designers of storm overflow treatment facilities must be cognizant--process efficiency should not be considered in the usual terms of percent removal used in municipal treatment. It was found during the microstrainer operation, that due to extreme variation of the influent suspended solids concentration, removal efficiency would also vary, while the more desirable, effluent concentration remained relatively constant at approximately 10 mg/l and less. For example, a typical effluent concentration of 10 mg/l suspended solids would yield

a reduction of 99.0 percent for an influent concentration of 1,000 mg/l, whereas the suspended solids reduction would be only 50 percent if the influent concnetration were 20 mg/l. This phenomenon is apt to reoccur in other physical-chemical stormwater treatment operations.

Increased flow rates greatly reduce capital costs and space requirements. Increased throughputs have also been obtained with other fine-mesh screening processes(41,88,89), fiberglas filtration(90,91,92), and, with dissolved-air flotation(41,93,94,95).

A USEPA study that was conducted in Cleveland, Ohio(96,97) showed high potential for treating combined sewer overflows via ultra high-rate filters using anthrafilt and sand within a 7 to 8 foot deep bed. Figure 6 depicts the three-six inch diameter filter column arrangement, a major portion of the pilot plant at the Cleveland site. With the high loadings of 16 to 32 gpm/ft^2 surface area, removal of solids is effectively accomplished throughout the entire depth of filter column. This compares to conventional filters operating in the range of 0.5 to 5 gpm/ft^2 where solids are essentially only eliminated in the first few inches of filter media. A rough pre-treatment provided by a 40 mesh rotating drum screen was required to allow longer filter runs. Encouraging results(96) indicated removals of 35 and 68 percent for BOD and suspended solids, respectively, at the high hydraulic loading of 24 gpm/ft^2. Supplemental test work further showed process efficiency in regard to suspended solids removal can be achieved up to and exceeding 90 percent, and BOD removals can be upgraded to fall between the range of 57 to 80 percent, through the addition of poly-

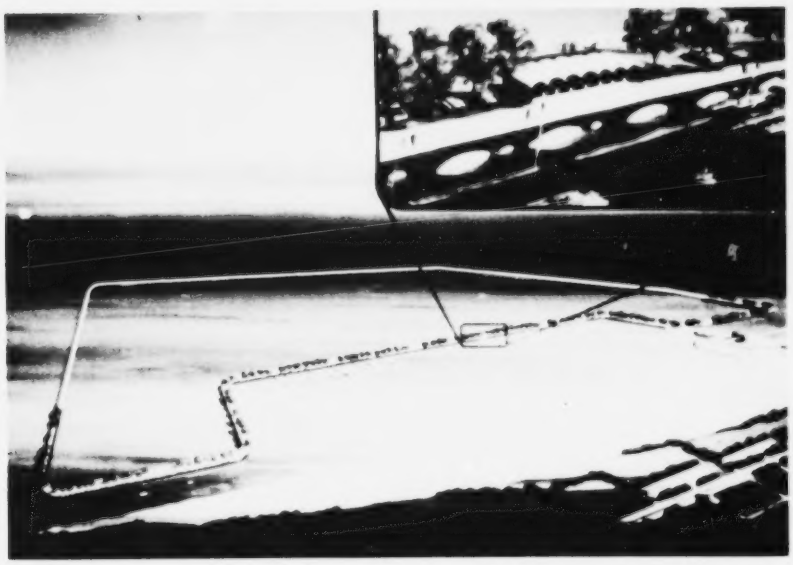

Figure 5. Conceptual design of combined sewage retention-stabilization basin, Cleveland, Ohio.

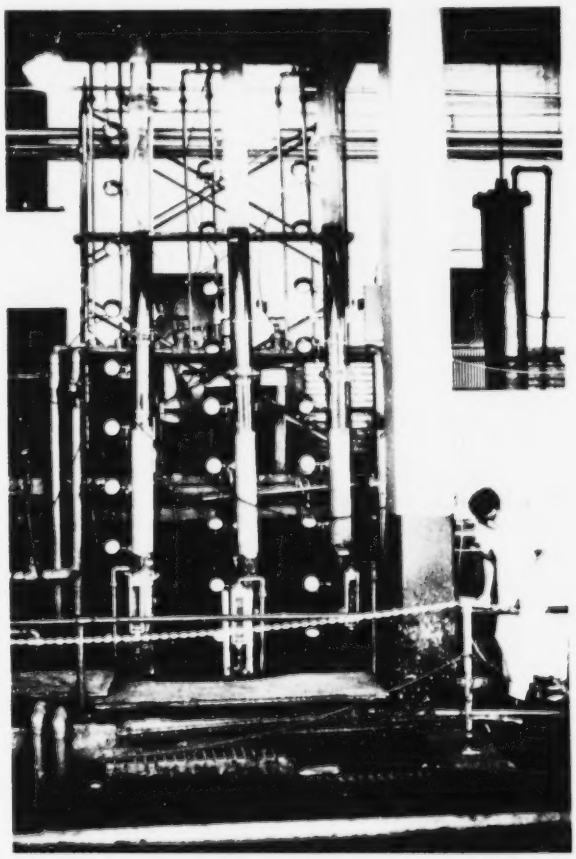

Figure 6, View of deep bed, dual media, high rate filter arrangement, Cleveland, Ohio.

electrolytes and sometimes alum. Substantial reductions, in the order of 30 to 80 percent of phosphates can also be obtained in this deep-bed, high-rate filtration system via addition of appropriate chemicals.

When dealing with combined sewer overflows, we are much more concerned with treating high flow rates and optimizing absolute waste loads removed. With ultra high-rate filtration we are willing to sacrifice some loss in percent waste reduction for short peak periods if in turn we can handle loads some 6 to 25 times greater than that accepted across a conventional filter. With this in mind, it is brought to your attention that the filter pilot plant efficiencies were determined under constant hydraulic loads, whereas in reality a plant will reach or exceed overflow design capacity only a small fraction of total operating time. Therefore, average overall removals will be higher in a real situation.

Results from a 5.0 MGD screening and dissolved-air flotation demonstration grant pilot plant in Milwaukee, indicate that greater than 70 percent removals of BOD and suspended solids are possible(41,93). This facility is considered a pilot plant only because of the very large magnitude of storm flow generally dealt with. For many sanitary sewage treatment plants today, it could be considered a full-scale operation. Findings reveal 95 to 97 percent reduction in suspended solids during first flushes and 85 percent reduction during extended overflows, and also better than 90 percent reduction in phosphate can be achieved as an additional benefit, by employing chemical coagulants. At the

present time, the Program is also sponsoring two air flotation treatment facilities at Racine, Wisconsin, having capacities of 20 and 40 MGD, respectively. Another dissolved air flotation plant is being evaluated in the San Francisco area(94) under the auspices of our Program, which has a storm runoff treatment capacity of 24 MGD.

A unique variation of the usual coagulation - adsorption, physical-chemical treatment process(98,99,100) is now being demonstrated for USEPA in Albany, New York. This system is comprised of a 0.01 MGD trailer mounted pilot plant where both powdered carbon and coagulants are added in a static mixing-reaction pipeline, and the resultant coagulated matter is flocculated downstream, separated by tube-settlers and polished by multi-media filtration. The project is also demonstrating regeneration of alum and activated carbon by fluidized-bed incineration.

Another demonstration project in Milwaukee has studied a new biological process(101,102), described as the rotating biological contactor consisting of a series of shaft-mounted rotating disks. Similar in principle to trickling filtration, a biological growth attaches onto the disks. Under steady loading rates, efficiencies exceeding those of the trickling filter have been attained, but a surge tank appears essential. Figure 7 illustrates the rotating biological contactor in operation, and Figure 8 gives a close-up of the rotating disks.

Another approach in overcoming the extreme variation in overflow rates is to provide surge facilities prior to the storm treatment plant or the municipal plant. The surge basin(s) (or existing combined sewers) could furthermore serve a dual function in equalizing not only

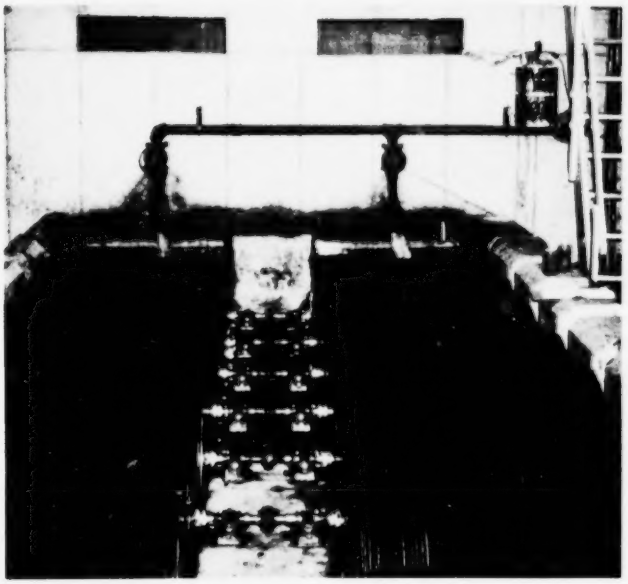

Figure 7. Overall view of rotating biological disks, Milwaukee, Wisconsin.

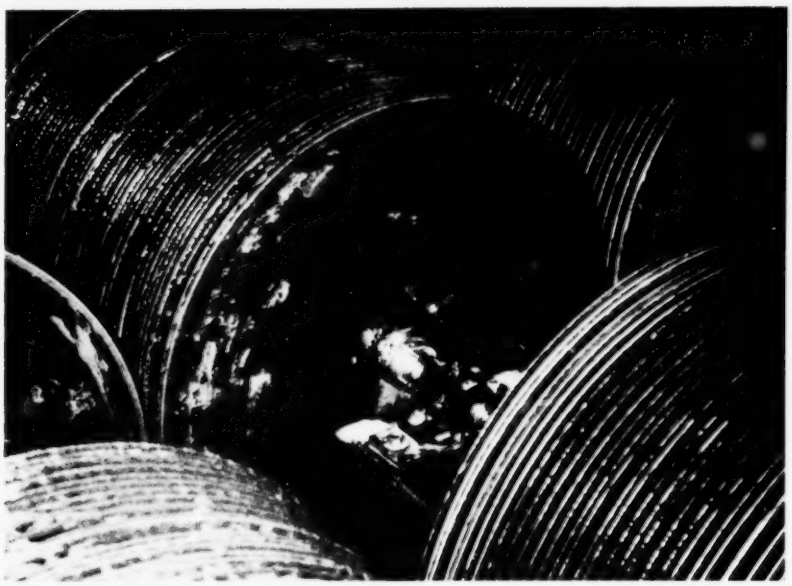

Figure 8. Close-up of rotating biological disk, Milwaukee, Wisconsin.

wet-weather flows but dry-weather flows as well. In this way, a single future treatment system can readily be designed for storm and sanitary flow conditions. This could also assist presently overloaded sanitary plants in obtaining more uniform operation. Short-term storage incorporated into the treatment plant would even out the daily cycle of dry-weather flows allowing for more efficient use of the treatment process over the entire 24 hours. Equalization would permit reduced treatment process design capacity. Further analysis is necessary to determine the most economical break-even point between the amount of storage versus the treatment capacity.

The Sewerage and Water Board of New Orleans is carrying forth a demonstration project on the use of sodium hypochlorite for disinfection of storm flows as high as 11,000 cubic feet per second (cfs), to both reclaim and protect public bathing beaches(14,15,53). In order to economically provide the large quantities of disinfectant required, an on-site hypochlorite batching plant was constructed. Figure 9 shows the batching plant, and Figure 10 gives a view of the massive-size chlorine contact basin under construction. The basin has since been completed as illustrated in Figure 11. The basin is a forebay to the major drainage pumping station. Another method of on-site generation of hypochlorite in this case by electrolysis, is being conducted for the USEPA in the Boston area.

The disinfection of combined sewage entails certain differences, which make the design and operation of facilities difficult when compared to sanitary sewage. The highly varying qualitative and

Figure 9. Stormwater disinfection project - hypochlorite batching plant, New orleans, Louisiana.

Figure 10. Stormwater disinfection project-chlorine contact basin under construction, New Orleans, Louisiana.

quantitative character of the storm generated inflows require disinfectant dosages to be based on a predicted rather than an established technique. Bernarde, et al.(103), have shown the importance of the temperature variable in their highly controlled disinfection studies. Specifically, with the following held constant: pH, initial bacteria count, and chlorine dioxide dosage, it required five times as much contact time to obtain a 99 percent kill at 5°C (40°F) as it did to obtain the same kill at 30°C (80°F). This points to the importance of temperature in addition to the usual (time and dosage) disinfection control parameters, as temperature is apt to have a much wider range during the year for runoff waters than it does for domestic sewage flows. It may very well be, that the yearly temperature fluctuation in combined sewage in many urban areas would be similar to the range (40°F to 80°F) tested for by Benarde, et al., and as a result, require disinfectant dosage to vary seasonally or as effected by ambient temperature.

We are also searching for high-rate disinfection systems, to save on large tankage requirements for the high storm flow rates encountered, with the help of more rapid oxidants (such as chlorine dioxide(104)), and by imparting greater turbulence to the flow. Successful attempts toward high-rate disinfection are being noticed at our Philadelphia Pennsylvania(87) and Onondaga County, New York(104) demonstration sites. The Philadelphia project(85) is also making an evaluation of ozone, generated on-site for disinfection pruposes. Another study(92) proposes the use of combined halogens (chlorine and iodine) to provide more effective disinfection of viruses as well as bacteria in a swimming lake. This

study(92) also supports dechlorination by activated carbon or use of ozone, with a relatively short half life, in lieu of chlorine to alleviate residual toxicity problems to fish life.

C. Combinations

When a single method is not likely to produce the best possible answers to a given pollution situation, various treatment and control measures--as previously described--may be combined for maximum flexibility and efficiency. One such combination might be: in-sewer or off-system storage for subsequent overflow treatment in specifically designed facilities, followed by groundwater recharge or recovery for water sports and aesthetic purposes. Another combination might be flow retention with pump or gravity feed-back to the sanitary sewerage system.

The temporary storage concept, previously discussed as a control process, also provides for a certain degree of treatment by settling, for excessive overflows greater than the design storage capacity discharging directly to the receiving stream. Likewise, this settling potential for flows less than design capacity together with on-site solids disposal usually overlooked, should be definitely considered. The proposed prototype demonstration for Lancaster, Pennsylvania, previously cited, plans to microstrain and disinfect discharges greater than the storage capacity of the "silo" structure. Bio-oxidation of stored flows may also be taking place. For example, open retention ponds or lagoons can be designed to provide both equalization and stabilization. A prototype lagoon installed in Springfield, Illinois(105)

has given good information on how to proceed with future design. Results indicated a moderate degree of treatment, however, undesirable levels of algae were present in the lagoon effluent. Future stabilization basins should consider periodic solids removal, and multi-cell installations. Shelbyville, Illinois is now involved in a multi-celled treatment lagoon project. Another lagoon approximately 40 feet deep, employing both aerobic and anaerobic decomposition, is presently being evaluated in East Chicago, Indiana.

Mt. Clemens, Michigan is proceeding with a project involving discharge of combined sewage overflows into a series of three "lakelets", each equipped with surface aerators. Effluents will pass from one pond to the next through microstrainers, and the final effluent will be chlorinated. This control and treatment scheme is designed to have no adverse aesthetic impacts, and the possibility of reusing these waters for recreational purposes will be explored.

A conceptual engineering study for the Washington, D.C. area(92) has shown that it would be feasible to construct a control-treatment facility to handle combined sewer overflows up to 3,000 cfs. A 175 million gallon storage facility is tentatively planned with an overhead parking garage, coupled with a 50 MGD high rate filtration-adsorption-disinfection plant. This treatment complex is intended to produce reclaimed waters suitable for swimming, boating, and fishing.

Our Program has refined and is demonstrating the vortex flow regulator/solids-liquid separator(41,42,43,60,106,107,108) which has had a successful history in England. The device is of simple annular-

shaped construction requiring no moving parts. It provides a dual function, regulating flow by a central circular spillway, while simultaneously treating combined sewage by vortex action which imparts liquid-solids separation. The low-flow concentrate is diverted to the sanitary sewerage system, and the relatively-clear liquid overflows the spillway and receives further treatment or is discharged to the stream. Figure 12 shows an overall view of the vortex unit with the influent, low-flow concentrate, and overflow effluent lines visible. Figure 13 contains a plan view of the device with the fluid action and clean overflow visible. Figure 14 shows the empty vortex with a view of the bottom dry-weather effluent channel. This device is capable of functioning efficiently over a wide range of combined sewer overflow rates having the ability to effectively separate settleable and light weight organic suspended matter at a small fraction of the detention time required for conventional sedimentation. For these reasons serious thought is now being given to the use of vortex units in series and in parallel solely as wet-weather treatment plant systems. Great Britain has also developed a helical or spiral type regulator/separator based on similar principles as the vortex device(41,42,43).

D. Flow Measurement

The quantitative and qualitative measurement of storm overflows is essential for process design, control, and evaluation. The "urban intelligence systems" previously mentioned (under Section V.2.a.) require real-time data from rapid, remote sensors in order to remotely

Figure 11. Stormwater disinfection project-chlorine contact basin construction completed, New Orleans, Louisiana.

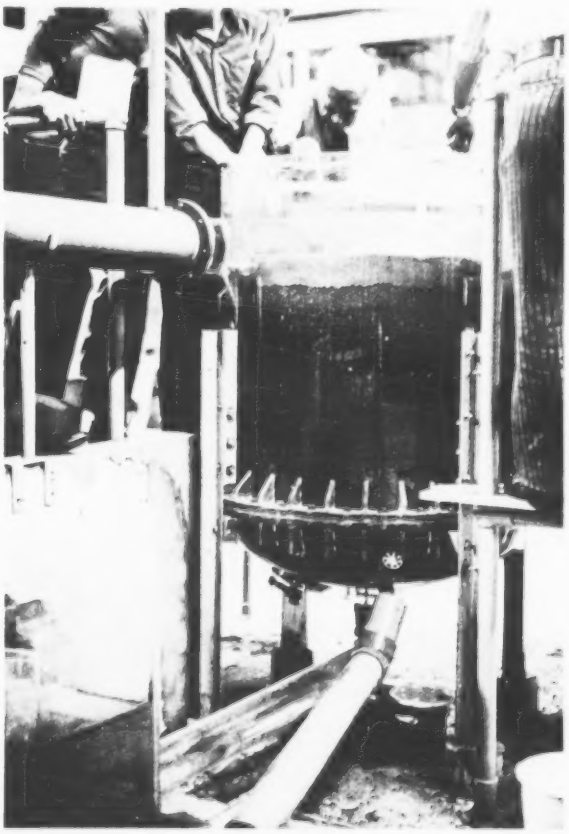

Figure 12. Overall view of vortex flow regulator/solid separator pilot study for Lancaster, Pa. Grant No. 11023 GSC, La Salle, Quebec.

Figure 13. Plan view of vortex device depicting fluid action, LaSalle, Quebec.

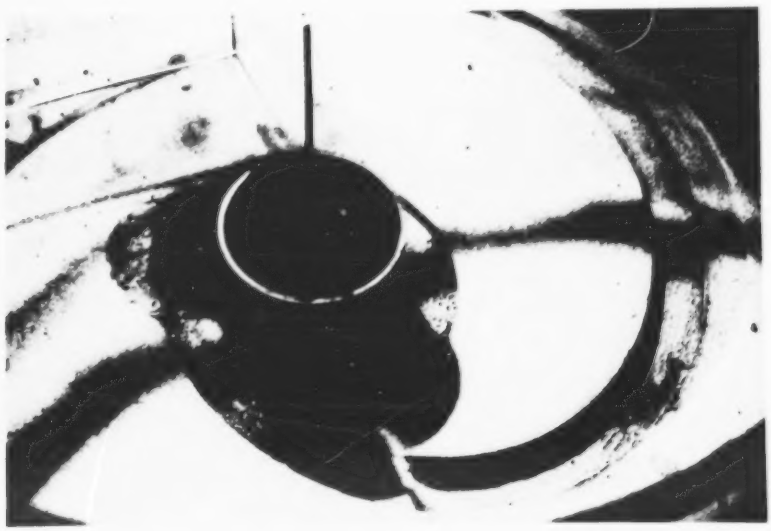

Figure 14. Plan view of empty vortex device with bottom dry-weather effluent channel visible, LaSalle, Quebec.

control a sewerage network. Conventional flow meters have been developed mainly for relatively steady-state irrigational, stream and sanitary flows, and not for the highly-varying surges encountered in combined sewers. In a combined sewer, a measuring device may be subjected to very low flow rates, submergence, reverse flow, and surcharge, all during a single rainstorm. These severe flow conditions rule out the reliable and accurate application of conventional devices, such as, weirs and flumes at many locations. Consequently, the Storm and Combined Sewer Pollution Control Program is deeply involved in the development and demonstration of sophisticated and new flow measuring equipment utilizing the various principles of: vibratory damping, hot-film anemometers, electrical capacitance of induced foreign matter, and ultrasound. A dual Venturi flume - Venturi meter and a magmeter for both open channel and pressure flow conditions are also being evaluated.

Our Program has contributed towards the development of a prototype monitor capable of instantaneous, in-situ, rapid measurement of suspended solids based on the optical principles of light depolarization(106,107). At one demonstration site an in-situ suspended solids meter utilizing photometrics is also being evaluated. This instrument appears promising and may have the needed ability to overcome interferences from color or dissolved matter.

E. USEPA Stormwater Management Model (SWMM)

The capability to analyse various component flows and pollution loads throughout a sewerage system is one of the keys to better design

of control and treatment systems. Due to complexities of the rainfall-runoff-flow phenomena, past analyses have been less than adequate, resulting in poor estimates of flow and predicted system responses to a storm. By virtue of previous undertakings, our Program now has available an operational "descriptive" mathematical model(112,113,114,115,116, 117,118) which can overcome former analytical deficiencies. The model has been demonstrated at five combined sewer sites throughout the country, varying from 187 to 5,400 acres. During demonstration the SWMM has been verified(113) to be capable of representing the gamut of urban stormwater runoff phenomena for various catchment systems. This includes both quantity and quality, from the onset of precipitation on the basin, through collection, conveyance, storage, and treatment systems, to points downstream from outfalls which are significantly affected by storm discharges. The computer program(115) is intended for use by municipalities, government agencies, and consultants as a tool for evaluating the pollution potential of existing systems, present and future, and for comparing alternate courses of remedial action. Use of correctional devices in the catchment and their cost/effectiveness evaluation has been demonstrated also. It is still felt that simplification of the SWMM program should be explored, as long as model output is not impaired. Other models to assist in the complicated challenge against wet-weather pollution have also been developed and utilized(9,11,78,119,120).

We are now in the initial phase of demonstrating the application of this method for "decision-making"(108,117), that is, its ability

to analyse a major combined sewer system; to select and to design control and treatment approaches based on cost/effectiveness; and to design a computerized means of overall management of the system during storm flows. It is the eventual goal to handle all (wet and dry-weather) flows in this manner.

VI. PROGRAM PROJECT NEEDS

Looking ahead, the Storm and Combined Sewer Pollution Control Program needs are vast and numerous. At present, we are considering the award of demonstration grants to State and local governments for the evaluation of the following full-scale prototype treatment processes:

A. Deep-bed, multi-media, ultra high-rate filtration,

B. Physical-chemical processes including the concepts of in-line or in-pipe coagulant mixing and activated carbon adsorption with on-site regeneration of coagulants and carbon,

C. Vortex treatment systems, and

D. Helical (or spiral) flow regulation/solids separation.

Special consideration should be given to adapting these processes for dual treatment of dry and wet-weather flows, as well as for automated control. Wet-weather treatment systems built in conjunction with existing sanitary plants can demonstrate their synergistic benefit by polishing secondary dry-weather effluents or increasing dry-weather treatment capacity during the vast majority of the time, when it is not raining.

There are also certain major control methods requiring further development. "Upstream" storage or other control processes to decrease the storm-water runoff effect on lower portions of the system is one case in point.

An example of this would be the temporary storage or attenuation of stormwater at the building or immediate area through the use of holding tanks; seepage pits, possibly for recharge(121); roof tops(121); parks and play grounds(121); backyard detention facilities; porous pavement(70), previously discussed or neighborhood, decentralized stormwater collection sumps including storage facilities under streets(122). Upstream control systems should automatically regulate discharge from storage to the groundwater, a watercourse, or sewer system. Plans for reuse of stored water for irrigation, street cleaning, sewer flushing, aesthetic and recreational ponds(92, 123), potable supply(124) and other purposes is also encouraged(121,125,126).

Another "so-called" control practice, requiring further study is the conventional employment of catch basins. We are seeking answers to such questions as:

1. What is their actual need as used today?
2. Can new types be developed or existing ones be improved?

And very importantly, with wet-weather control requirements evident(127 128.129,130,131,132,133), now is the time to encourage our colleges and universities to cover the concepts of stormwater runoff and combined sewer overflow pollution in their graduate school curriculum on water pollution control. After all, the students of today will be the problem solvers of tomorrow.

Many more ideas and concepts could be added--some may be more significant than those discussed. Submission of ideas, project proposals or grant applications to the USEPA is strongly encouraged. Some of the criteria for evaluating such proposals includes:

A. Overall budget appropriation for research, development and demonstration projects.

B. At least 20 percent of the total project cost should be allocated for research, evaluation and study efforts.

C. Minimal duplication of past or on-going projects. However, some duplication may be necessary in order to provide evaluation under suitable variety of conditions, and

D. The proposed development or demonstration should have nationwide importance and application as opposed to having limited geographical use.

VII. CONCLUSION

The Storm and Combined Sewer Pollution Control R&D Program has implemented many projects directed to full-scale treatment and control. Most of these projects are still under construction or evaluation, and we are presently awaiting operational results.

This paper has been limited to pollution abatement of combined sewer overflows. However, it should be noted that similar technological application can and should be employed for the treatment and control of separate stormwater runoff.

Abatement or prevention of pollution from stormwater runoff and combined sewer overflows is one of the most challenging areas in the sanitary engineering field. The facts of life - from an engineering standpoint - are difficult to face in terms of design and cost. Operational problems can be just as foreboding.

The full impacts of "marginal" pollution, particularly that caused by uncontrolled overflows, must be recognized now, and planning initiated, to improve sewerage system efficiencies and so bring all wastewater flows under control. Municipal programs with this objective cannot begin too soon because corrective action is time-consuming. Efforts devoted to improving sewerage systems will pay significant dividends in complete control of metropolitan wastewater problems and pollution abatement. Research and development being undertaken cooperatively by Federal, State and local entities, including industry and the academic world, are majing available important answers on the most efficient and least costly methods needed to restore and maintain our water resources for maximum usefulness to man.

It is clearly seen that abatement requirements for combined sewer overflow (and stormwater runoff(133)) pollution are forthcoming. Already, Federal, State and local governments(127,128,129,130,131,132,133) have promulgated wet-weather flow treatment and control standards and guidelines. The USEPA Research and Devleopment Program will continue its intensive efforts as a prime support for this real-world application.

VIII. ACKNOWLEDGEMENTS

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